CONVEYOR OVEN HAVING AN ENERGY MANAGEMENT SYSTEM FOR A MODULATED GAS FLOW

This is a continuation-in-part of Serial No. 09/760,194 filed January 12, 2000, which, in turn, was a formal application replacing Provisional application Serial No. 60/249,685, filed November 17, 2000.

This invention relates to conveyor ovens having reduced fuel consumption and with quieter operation, and more particularly to such ovens having an energy management system including a modulated gas flow with a safety feature that isolates electrical controls in order to enhance an integrity of the safety features built into the oven.

BACKGROUND

Prior art conveyor ovens are shown in U.S. patents 4,964,392 and 5,277,105 owned by the assignee of this invention and in the references cited on the cover pages of these patents. These and other similar patents may be consulted in order to learn details of how conveyor ovens are constructed and operate. Often -- but not always -- this type of oven is used to cook or bake pizzas, bread, or the like.

Conveyor ovens are devices for automatically baking or cooking food products over timed periods. Normally, they have a conveyor belt which travels through an elongated oven cavity having open ends and at a speed which times the exposure of the food product to the heat of the oven. A food product, such as a pizza, for example, is placed on one end of the conveyor at the entry to the oven cavity and delivered from the oven at the opposite end of the cavity. The heat in the oven and the speed of the conveyor are coordinated so that the food product is fully and correctly cooked or baked by the time when the conveyor delivers it at the exit end.

The conventional method of delivering controlled heat has been to switch burners off and on in order to hold the resulting temperature in the oven cavity within a relatively narrow range. This process has functioned very well in the past. However, anything can always be improved and, therefore, it is always possible to do a better job heating and cooking or baking the food product.

Also, the cost of the fuel (natural or propane gas) for the burners is increasing sharply. Thus, an important goal is to reduce the fuel consumption, which the invention has done by approximately 30%.

A conveyor oven is usually energized by gas, which always requires a safety feature since an explosive atmosphere might be created by leaking gas. As a result, various governmental agencies prescribe an incorporation of safety features, such as a cut-off valve, into the design of the oven. It is important for the oven controls to be designed to not only enable a reliability of these safety features, but also to provide a redundancy for the safety features. In this invention, the safety features are enhanced by providing an electrical isolation between control signals that might otherwise cause a feed back that might enable the oven to continue operation or to re-ignite after a demand for shut down.

BRIEF DESCRIPTION OF THE INVENTION

Accordingly, an object of the invention is to cook or bake a better food product by maintaining a closer control over the uniformity of the heat in the oven cavity. Here, an object is to maintain a substantially smooth level of heat after the oven is switched on and continuing throughout the oven operation. In particular, an object is to avoid the

peaks and valleys of heat swings as the burner switches on and off as it hunts for the targeted temperature.

Another object is to provide a quieter operation by eliminating a blower-like noise which occurred heretofore as the burner switched on.

Still another object is to provide a universal heat controller which can control either a modulating valve or an on/off valve, thereby eliminating a need for many controllers individually dedicated to specific ovens.

A further object of the invention is to provide a control circuit which insures the integrity of a safety feature built into the oven. Here, an object is to provide a self-healing control which so insures the integrity, but which does not require a replacement of a fuse or other element after the condition requiring a safety valve operation subsides.

In keeping with an aspect of the invention, these and other objects are accomplished by a use of a modulating valve which increases or decreases the amount of the gas flow to a burner without fully switching the burner off or on during a bake cycle. The modulating valve is controlled responsive to temperatures sensed by thermocouple sensors located in the oven. Furthermore, the controller is also able to control an on/off gas valve in response to the same type of sensor signals, so that the same controller may be used universally for both the modern oven using the modulating valve and the older ovens using on/off valves.

The integrity of the safety features built into the oven is preserved by an isolation in the electrical control circuit between the elements which control the modulating valve. and a conditioner which converts signals from sensors into signals which can enable an

operation of the modulating valve. This isolation prevents feed back which might otherwise cause the modulating valve to behave in a way which would defeat the shutdown of an on/off safety valve. In order to provide a self-healing of this integrity insuring system, it uses transformers for separating and isolating the modulation valve control and conditioner circuits from an ignition control module.

The advantages of the invention are many. There is an improved reliability and a higher quality bake at a shorter bake time and at a lower average temperature. Since the ovens operate at a lower temperature, the components are in a cooler environment which extends their life. The oven is quieter and the energy management system is more efficient due to a use of the modulating gas valve and to a two-way air return, with less turbulence, creating lower DB noise levels. There is an increased flexibility making it easier to rearrange the fingers for delivering heated air to the food product. There is an ability to add a deck, as volume increases, or to remove a deck if volume falls off. All decks are the same.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from the following specification taken with the accompanying drawings, in which:

Fig. 1A is a perspective view which shows a plurality of ovens stacked one upon the other in order to increase baking capacity without increasing the oven footprint;

Fig. 1B is a perspective view of a hot air delivery finger being removed from the oven cavity;

Fig. 1C is a perspective view of a disassembled finger;

Fig. 2 is an enlarged view of that part of Figs. 1A-1C which is material to the invention;

Fig. 3 is a view, partly in cross section, of an automatic safety on/off switch and a modulating switch coupled into in a gas line;

Fig. 4 is a schematic line drawing of the parts seen in Fig. 2, together with labels identifying the various items shown in the drawing;

Fig. 5 is a graph which illustrates the peaks and valleys of the burner duty cycle of the prior conveyor ovens using on/off gas valves;

Fig. 6 is a graph which illustrates the continuous burner operation responsive to the inventive modulated gas flow;

Fig. 7A and 7B are simplified cross sections showing a side elevation and a plan view which schematically show the location of temperature sensors in the oven;

Fig. 8 is a control circuit diagram of the oven, the control circuit including an energy management system with a safety integrity enhancement; and

Fig. 9 is a flow chart showing the capability of the controller for the modulating valve.

DETAILED DESCRIPTION OF THE INVENTION

The equipment in Figs. 1A-1C shows a conveyor for delivering a stream of heated air through an oven cavity. More particularly, Figs. 1A-1C are perspective views of a conveyor oven 20 which receives a conveyor 21 (Fig. 1A) extending from an input end 21a through a cavity to an output end 21b of the oven. The motor for driving the conveyor is in the housing 22.

Fig. 1A shows a plurality of the ovens 20a-20b (sometimes called "decks") stacked one on the other to increase the baking capacity without increasing the footprint dimensions. Each deck may be separately programmed to bake a different food product. Fig. 1B is a perspective view of a person removing a hot air delivery finger from an oven by sliding it in direction A along side rail tracks. Fig. 1C is a perspective view of the finger construction where two perforated plates 25a, 25b direct streams of hot air downwardly and onto the upper surface of a food product. Lower fingers 24a (Fig. 1B) direct hot air upwardly through perforated plate 25c and onto the lower surface of a food product. The hot air recycles by flowing from a plenum, through the fingers and returning between the top and bottom fingers to the plenum.

The material parts 26 of the oven energy management system are shown in greater detail in Figs. 2 and 4. Natural or propane gas is fed from a source to the burner via a line 28 and a modulating valve 30 under the control of a signal conditioner 31 and a temperature controller 32. Both the preferred modulating valve 30 and signal conditioner 31 are products of the Maxitrol Company and are sold under the trademark "Selectra". The Maxitrol Company has a business address at 23555 Telegraph Rd (P.O. Box 2230), Southfield, MI, U.S.A. 48037-2230. The temperature controller 32 is a product of the Honeywell Company.

Fig. 3 shows gas line 28 extending from any suitable source of natural or propane gas on the left to a burner on the right. Interposed in the gas line between the source and the burner are two valves 29 and 30. Valve 29 is any suitable on/off valve usually prescribed by a governmental regulatory agency for safety purposes. For example, a conventional valve 29 might be adapted to shut down the gas delivery

responsive to predetermined conditions such as excessive pressure appearing in the gas supply line, excess oven temperature, or the like.

The modulating valve 30 means is shown in cross section. A main spring 33 biases a main valve 34 into a position either to close or open the gas line 28 in order to prevent or enable a flow of gas to the burner. A by-pass line 35 is provided for enabling gas to flow around the main valve 34 and through a pressure regulator 36 even when valve 34 is closed, thereby continuously maintaining at least a minimum level burner operation. A manual valve 37 in the by-pass line may cut-off or allow the by-pass gas to flow, as a safety or shut down procedure. Midway between regulator 36 and the manual by-pass valve 37, a tap line 38 allows the by-pass gas to flow through modulator 39 in order to enable the gas to flow from the source into an upper chamber 40 which is closed by a diaphragm 41. Modulator 39 is controlled responsive to signals from thermocouple sensors 42 in the oven. As the oven becomes colder, the diaphragm moves down, and as it becomes hotter, the diaphragm moves up. Hence, the diaphragm 41 moves up or down as a function of the instantaneous oven temperatures.

As the diaphragm 41 moves down, it overcomes the bias of spring 33 and opens main valve 34 by a distance which enables a volume of gas to flow in line 28 depending on the distance that valve 34 has moved.

If the oven temperature sensed at 42 goes down, the modulator 39 enables more gas flow from the by-pass line 35 to increase pressure in upper chamber 40, thereby deflecting the diaphragm 41, pushing valve 34 against the bias of spring 33 and opening the main valve 34 by a discrete distance. If the oven temperature sensed at 42 goes

up, modulator 39 restricts the flow of by-pass gas, the pressure in upper chamber 40 reduces, the diaphragm 41 returns somewhat from its deflected condition, and spring 33 pushes the valve 34 to a more closed position.

Hence, it should now be clear that the amount of gas delivered to the burner follows the instantaneous fluctuations of the oven temperature, while maintaining a minimum flow through by-pass line 35. With a need for a low heat, there is little or no pressure on the diaphragm 41 and gas flows only through a by-pass and at a very low rate. In between the high and low demands for a high level of heat and a low level of heat, the pressure in the upper chamber 40 has an intermediate effect upon the deflection of diaphragm 41 and, therefore, on the position of main valve 34 and the amount of gas flowing to the burner.

The temperature controller 32 (Fig. 2) is a device which receives a signal, preferably, from a pair of thermocouple sensors located in the baking cavity of the oven. The sensor may continuously supply any convenient signal indicating the instantaneous oven temperature. The signal conditioner 31 interfaces between the temperature controller 32 and the modulating valve 30 by converting the sensor signal into a signal which the modulating valve uses.

The details on the arrangement of the various parts described thus far are best seen in Fig. 4. The gas is delivered from any convenient source through a line 44 to the various ovens via a pipe 28. As here shown, it may be assumed that pipe 28a is in oven 20a (Fig. 1A) and pipe 28b is in oven 20b. The remainder of the ovens 20c, 20d are served in a similar manner. The top oven has a pipe 28a which is closed by a cap 46.

The manual shut-off valve 48 simply provides for a complete shut down of the system. Usually, this valve is left in an "on" position.

The automatic valve 29 is a conventional on/off device which meets any local safety standards. While such safety valves tend to be fairly uniform, various locations may have their own, non-standard governmental requirements. Therefore, the valve 29 has special meaning depending upon the geographical location of the oven.

Next, the modulating gas valve 30 is located to admit a regulated amount of gas into a burner 50. While any suitable burner may be used, a high efficiency burner is preferred. These burners are found in many appliances from heavy duty home heating to relatively light duty in appliances.

A blower 52 is coupled to the burner 50 via a suitable duct 54 in order to supply combustion air to the burner. When the burner first comes on there is a mixture of gas and forced air, which usually produces a very noisy roar; hence, a blower which switches off and on is noisy. The invention avoids this noise by modulating the flow of gas which never shuts off as demand increases and decreases when the oven temperature decreases or increases.

Fig. 5 is a graph which discloses at 56 the duty cycle of the prior art burner as it responds to the temperature sensed in the oven and at 58 the temperature fluctuations at various locations in the oven. The prior art burner duty cycle 56 is shown as having peaks 60a, 60b, 60c, as the burner is generating maximum heat and valleys 62a, 60b, 60c when the burner is shut down. The peaks and valleys depend upon sensed oven temperatures. Those temperatures vary with ambient temperatures, drafts, frozen or thawed condition of the food product, etc. Hence, it is not possible to predict with any

certainty as to the relationship between the appearances of the peaks and valleys relative to the excursion of the food product on the conveyor. As a result, the food product may have a variegated cooking or baking depending upon the peaks and valleys.

A second point indicated in Fig. 5 is that there is a considerable demand for fuel because the oven heats and cools depending upon the peaks and valleys. Hence, the burner has to work harder to repeatedly recover from a cool down when it is in the off stage.

Fig. 6 is a graph similar to Fig. 5, but showing the operation responsive to the inventive use of the modulating valve 30. The flow of gas to the burner is seen in the curve 70. While the gas flow varies almost continuously, it is never off, so that the burner modulates its out put within a relatively narrow band but does not shut down. Since the burner does not come on suddenly, there is no blow torch-like roar at the ignition. Curve 72 shows the temperatures sensed at the front, exit and middle of the oven. While this curve shows that the sensor does track the instantaneous variations of the heat put out by the burner, the average temperature in the oven is much more uniform over time.

The most important feature is that, in the prior art, the fuel required to maintain the burner operation represented by curve 56 (Fig. 5) is 30% greater than the fuel required to maintain the inventive burner operation represented by curve 70 (Fig. 6).

Figs. 7A and 7B are simplified and schematic showings of the side elevation and top plan view of the inventive oven and are provided to show the location of two oven temperature sensors which feed the controller 30. In greater detail, the features shown

in Figs. 7A and 7B are the oven housing 75 that contains a rear wall 76 and blower fan compartment 77 which together define an air supply plenum 78 between them. This plenum is pressurized by hot air that is driven into the oven via upper and lower fingers 79, 80, respectively. A conveyor 81 passes between the fingers 79, 80, carrying food products which are baked by the heat of the hot air discharged from the fingers. After the hot air is emitted from the fingers, it passes between the fingers and into an air return plenum 82, 83 above and below the fingers.

The oven contains three thermal couples which are seen in line in Fig. 7A so that only a high limit thermocouple sensor 84 appears. The high limit sensor 84 causes the oven to shut down if a predetermined threshold temperature is reached. This shut down is well below a hazardous level. The other two of these thermocouples which feed controller 32 are the control sensors 85, 86 seen in the plan view of Fig. 7B.

The controls are in a compartment 82 at the front of the oven which is cooled by fans seen in Figs. 8 and 9.

Fig. 8 is a circuit diagram showing a control section 108 relating to the mechanical aspects and a control section 110 relating to the energy management system of the inventive oven.

The mechanical aspects 108 include blower motors 113, 114 which are connected to a suitable commercial power source 112 via switches (such as 115) and circuit breakers (such as 116). The blowers 76 are in the plenum 82 to drive a stream of hot air into the oven cavity which is recycled between the fingers and back into the plenum. The high limit thermostat 118 does not normally provide an active function unless the temperature in the oven exceeds some preset threshold safety limit, beyond

which the oven might go into a runaway condition. If that limit is exceeded, the contacts 120 open to shut down the oven while contacts 122 close to light a reset pilot lamp 124.

Next, there is a series circuit 126 of door switches which will prevent the oven from operating unless all doors are suitably closed. If there are any other mechanical parts which have to be in any particular condition for the burner to switch on, associated switches (not shown) may also be provided in the series circuit 126.

A power transformer 128 provides power to the conveyor motor 130 which is turned on/off at switch 132. The motor has a suitable sensing mechanism for maintaining a stable speed selected at and under the control of a known circuit in control box 134.

The energy management system 110 controls the heat in the oven by modulating the delivery of gas to the burners. More particularly, a set of switches 135 either enables or disables the blower. If the blower shuts down, the contacts 136A open and the oven cannot be placed in operation until the manual switch 136B is closed. A coil 146 is energized when the burner blower switch 135 is closed to provide an interlock when the blower is on. The two fans 142, 144 blow cool air over the electronic and other controls in the control compartment 87 in order to prevent a malfunction as a result of over heating.

The temperature controller 32 receives signals from two sensors 85, 86 located at plenum 78 in the front end of a hot air stream for supplying heated air in the oven. The controller 32 is a product of the Honeywell Company. The switches 152 detect the presence of the various air streams in the oven. Basically, these switches have air sails in the oven at a location where they are moved by the air stream in order to open or

close electrical switches. These sail switches are simply on/off switches to indicate the presence or absence of the air stream. Switch 155 is closed in order to heat the oven.

First and second isolation transformers 156, 157 supply 24V. power for the electronic equipment coupled to their secondary windings respectively. In particular, transformer 156 supplies an ignition module 158 while transformer 157 supplies signal conditioner 31, thereby isolating the two from each other. The controller 32 is supplied from the power line 112. Signal conditioner 31 responds to signals which it receives from the controller 32 and converts them into signals which control the modulating valve 30. A push button 159 must be pressed to reset the modulating valve 30 after it shuts down.

An ignition module 158 is adapted to ignite and maintain a pilot flame that initiates the gas of burner 50 (Fig. 4). An associated sensor 160 signals the presence of a pilot flame. The safety gas valve shown at 29 has the characteristics prescribed by an appropriate governmental regulation in order to shut down the oven under predetermined hazardous conditions.

Means are provided to enhance the integrity of the safety features. Accordingly, even though there are many safety features on the oven so that it automatically shuts down well before any catastrophic condition is reached, it is conceivable that there could be a feed back condition in a loop extending between the controller 32, the signal conditioner 31, and the ignition module 158, which might interfere with the response of the safety valve 29.

Therefore, it is desirable to provide a safety integrity enhancement by the electrical isolation between the controller 30, conditioner 31 and ignition module 158, which would prevent such feed back.

The power line voltage (here 240V) applied at 112 appears across line conductors 162 and 164. Controller 32 is connected directly across the line so that there will not be any feed back to it via the line 162, 164 from either signal conditioner 31 or the ignition module 158. The two transformers 156 and 157 have primary windings 168 and 170 connected in parallel across the power line conductors 162, 164, so that the primaries are not affected by events after the secondaries. The secondary winding 172 of transformer 156 supplies the 24V power to ignition module 158 and to the governmental prescribed safety switch 29. The secondary winding 174 of transformer 174 supplies 24V to the signal conditioner 31 and modulating valve 30.

Hence, there is no single path forming a feed back loop for causing an interaction between the controller 32 and conditioner 31, and ignition module 158.

A layout of a front panel control panel is shown at the top of Fig. 9. There are a display panel and eight push buttons. A list of control panel functions are shown at the bottom of Fig. 9 to help explain the features of controller 32. The push button "1" is a blank which has no preselected purpose, but which is available to control any customized feature which the owner of the oven may request.

A four digit numeral display 200 displays either the process variables or the setpoint during normal operation. The right-most digit of this display shows whether the displayed value is in terms of degrees in Fahrenheit or in Centigrade. Alternate

information is also displayed during the service depending upon the function being carried out.

A "heat on" indicator is illuminated when the controller is applying an output of 3% or more heat. When an on/off control is configured, the "heat-on" indicator is illuminated when an output heat is provided. Either the present temperature or the programmed setpoint temperature may be displayed. A simultaneous pressing of both the unlock and the display keys 208, 202 will display the value of the heat output with the heat on indicator on. With the output unlocked at key 208, the user is able to cycle through actual temperature display indicators to reveal the actual temperatures, setpoint temperature, and the heat on condition. When the setpoint displays "yes", it is not possible to change the setpoint.

A locked setpoint condition can be temporarily unlocked at key 210 for making an adjustment of the programmed oven temperature. Sixty seconds later, the setpoint automatically returns to the locked state if no further control operations are carried out after the last press of the display key 202. When the 60 second time period expires, the controller 32 is locked and the display return to the default display.

The output display is automatically locked in a default display when a service man or operator places the controller in the service mode by pressing key 204 or when the hidden key 206 is pressed while the output display is shown. A failsafe condition occurs when any one of the various tests fail, at which time, a flashing signal display is alternately displayed with temperature.

If the oven has not reached 200°F within fifteen (15) minutes after an initial power-up of the oven, a message is flashed on the display panel indicating that the

controls need to be reset (power-cycled). If a thermocouple sensor fails to operate properly, the display will flash "open". If the polarity of the thermocouple leads are reversed, the display will flash a signal indicating the thermocouple leads are incorrectly connected to the instrument.

The displays also provide prompts for servicing the oven responsive to a simultaneous pressing of the unlock key 208 and the service tool key 204. Each additional press of the service tool key 204 advances the prompts in the order shown under "service mode" in Fig. 9. The user can continually sequence through the service prompts by repeatedly pressing the service tool key 204. The service mode is exited by either pressing the display key 202 or pressing no key for sixty seconds. Either way, the system automatically returns to the normal mode.

Setpoint lock key 210 automatically flashes the temperature that has been selected for an operation of the oven. The setpoint can be changed up or down by pressing either the increment or decrement keys 212, 214. The degrees (°F or °C) used for the prompts is changed by pressing either the increment or decrement keys. While at the degrees °F or °C prompt, a selection of "F" or "C" automatically changes the units of all the display to °F or °C. While the default display prompt is being displayed, an indicator flashes to indicate which display is chosen as the default display, which can be changed by pressing either the increment or decrement keys.

Those who are skilled in the art will readily perceive various modifications that fall within the scope and spirit of the invention. Therefore, the appended claims are to be construed to cover all equivalents.